

IMPROVED CONTACT FOR ERROR RESISTANT COUPLING  
OF ELECTRICAL SIGNALS

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**5 BACKGROUND OF THE INVENTION**

**Field of the Invention**

This invention relates generally to electrical connectors for electronic devices. More particularly, the invention relates to electrical contacts for use in electrical connectors to prevent the generation of spurious signals upon mating of the connector.

**Description of the Related Art**

Electrical connectors for use with peripheral electronic devices are well known in the art. A recurrent problem with many prior art connectors is the generation of spurious signals upon mating of a peripheral electronic device to an electronic system which is already energized. The connector may induce a voltage pulse into the energized electronic system. The voltage pulse may travel through the electronic system, thereby introducing spurious errors into the system. This problem is known in the art as the "hot plug" problem.

This condition that causes errors in electronic systems results from the very high data rates and very low energy of the signals within the systems. The input capacitance of the connector, printed circuit board lines and device capacitance of the buffer integrated circuit devices are the basis of the problem. Energy must flow from the system bus to charge this input capacitance, (generally tens of picofarads). When energy is removed from the system bus, a voltage pulse to an adjacent device on the bus occurs, thereby creating errors in the system. The voltage pulse may be

no greater than normal signals so no new radiated noise problem is introduced. However, it can cause data to be incorrectly transferred. Accordingly, the interconnections themselves are a large portion of the problem. This problem is universal since it affects both digital and analog electronic devices.

The prior art has generally addressed the "hot plug" problem by using logic and timing control circuitry, such as that which is disclosed in U.S. Patent No. 4,245,270, to slowly ramp up the voltage within the connecting line. However, providing the additional circuitry is complex and expensive.

Many connecting schemes require certain portions of the connector to be mated prior to other portions, or in a particular sequence. For example, with respect to power applications, U.S. Patent No. 4,079,440 discloses a circuit board having two connector plugs of differing lengths. The longer connector plug makes initial contact with a power line prior to the shorter plug, which reduces the onset of power surges. However, this scheme requires manual dexterity and specific insertion and removal timing for proper operation.

A connector assembly disclosed in U.S. Patent No. 4,747,783 attempts to eliminate timing and control circuitry for power applications. This connector assembly uses a long pin in the "plug" to first make contact with its mating "socket" to gradually increase the voltage to the socket until the entire plug makes mating contact with the socket. The plug comprises a pin having a thin insulating material covering the surface and a thin low resistive material covering the insulating material. When the plug makes initial contact with the socket, the current must pass through

the resistive portion of the plug. This permits the electronic components in the peripheral device to charge gradually and eliminates the current surges which may result.

5           This device is undesirable for several reasons. First, it requires the use of several contacts of differing lengths, thereby raising manual dexterity problems. Secondly, although the low resistance (i.e. 2-60 ohms) is sufficient to eliminate current surges in  
10 power transmissions, it is not sufficient to eliminate the voltage pulse from being introduced into the electronic system. In addition, the thin layer of low resistive material surrounding the thin layer of insulating material introduces an additional problem  
15 into the connection between the peripheral device and the electronic system; short capacitance. As explained previously, capacitance is undesirable in a connector.

It would be desirable to provide a signal connector assembly that would not introduce errors into an  
20 electronic system during a hot plug.

#### **SUMMARY OF THE INVENTION**

The present invention provides a plug contact having a high resistive portion within a plug for use in a signal connector assembly. When the plug of the  
25 assembly first makes contact with the receptacle contacts within a mating receptacle, the high resistive portion of the plug contact prevents a voltage spike. To prevent voltage pulses, resistive portions with resistances ranging from 10KW to 1GW are necessary  
30 depending upon the application. As the plug is further inserted into the receptacle, the energy flow is gradually increased. Eventually, the receptacle contacts within the receptacle pass the high resistive

portion and make contact with the conductive portion of the plug contact, thereby permitting transmission of valid signals without the generation of spurious errors.

In an alternative embodiment, the receptacle contact, or both the plug contact and the receptacle contact, may have the high resistive portion.

It is an object of the present invention to provide a connector assembly which permits connection of a peripheral device to an energized electronic system without introducing any spurious errors into that system.

Other objects and advantages of the present invention will become apparent after reading the detailed description of the presently preferred embodiment.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**Figure 1** is an isometric view of a simplified illustration of the present invention.

**Figure 2** is a graph of voltage versus distance traveled along the high resistive portion.

**Figure 3** is a graph of megaohms versus distance traveled along the high resistive portion with curves depicting varying thicknesses of the portion.

**Figure 4** is a graph of megaohms versus distance traveled along the high resistive portion with curves depicting varying resistivities of the portion.

**Figure 5a** is an alternative embodiment of the present invention with a tapered high resistive portion.

**Figure 5b** is an alternative embodiment of the instant invention with a stepwise-tapered high resistive portion.

~~A<sup>3</sup> > Figure 5c~~ is an alternative embodiment of the present invention with a resistive portion of mixed high resistive materials.

~~A<sup>4</sup> > Figure 5d~~ is an alternative embodiment of the present invention with a conductive barb in the high resistive portion.

~~A<sup>5</sup> > Figure 5e~~ is an alternative embodiment of the present invention with the high resistive portion extending into a hole in the conductive portion.

10 ~~A<sup>6</sup> > Figure 5f~~ is an alternative embodiment of the present invention with a high resistive housing.

~~A<sup>7</sup> > Figure 5g~~ is an alternative embodiment of the present invention with a high resistive inset in the housing.

15 ~~A<sup>8</sup> > Figures 5h and 5i~~ are an alternative embodiment of the present invention with a high resistance inset in the housing.

~~A<sup>9</sup> > Figure 6~~ is an illustration of the instant invention utilized on a circuit board.

20 ~~A<sup>10</sup> > Figure 7~~ is an illustration of the instant invention being used on a cylindrical connector.

~~A<sup>11</sup> > Figure 8~~ is an illustration of the various prior art connectors.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

25 The preferred embodiment will be described with reference to the drawing figures wherein like numerals represent like elements throughout.

~~A<sup>12</sup> > Referring to Figure 1~~, the preferred embodiment of the connector assembly of the present invention  
 30 comprises a plug 6 for mating with a corresponding receptacle 8. It should be recognized that although only one plug contact 7 is shown in detail for simplicity, there are typically at least two or more

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plug contacts 7 within every plug 6 for mating with corresponding receptacle contacts 15. The shape of the plug 6 is not central to the present invention. For simplicity, the plug 6 and plug contact 7 are illustrated as rectangular, although those of skill in the art will realize that many other shapes could be used without departing from the spirit of the present invention. The plug contact 7 comprises a conductive portion 14 which can be made from any conductive material, (such as brass, nickel, gold, copper or a superconductor, etc.) and a highly resistive portion 12.

The resistive portion 12 is generally rectangular shaped and extends across the width  $W$  of the plug contact 7. The resistive portion 12 comprises a layer of highly resistive material inset into the surface 16 of the plug 6, with a first end 11 of the resistive portion 12 exposed to the receptacle 8 and a second end 13 of the resistive portion 12 in contact with the conductive portion 14.

A typical receptacle 8 includes a receptacle contact 15 for each corresponding plug contact 7 which electrically mates with its corresponding receptacle contact 15 as the plug 6 of the peripheral device (not shown) is inserted into receptacle 8 of the electronic system (not shown).

A13> In operation, the first end of the plug 6 is inserted into the cavity of the receptacle 8. The receptacle contact 15 will make first contact with the resistive portion 12. Since it is contemplated that the electronic system will be energized, this will permit energy from the electronic system to begin flowing from the receptacle contact 15, through the resistive portion 12 and into the conductive portion 14 of the plug

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contact 7. The resistive portion 12 reduces the magnitude voltage pulses such that they will not present errors into the electronic system, as will be explained in detail hereinafter. A portion of the voltage "seen" by the plug 6 will drop across the resistive portion 12.

As the plug 6 is inserted further into the receptacle 8, the receptacle contact 15 passes along the surface 16 of the resistive portion 12 until it finally reaches the conductive portion 14 of the plug contact 7. When the plug 6 is fully inserted into the receptacle 8, the receptacle contact 15 will be in direct contact with the conductive portion 14 of the plug contact 7.

Accordingly, there will be no voltage drop across the resistive portion 12 of the plug contact 7. With respect to capacitance, the arrangement of the present invention specifically limits the capacitance between the metallic portions of the plug and receptacle contacts 7, 15, (it bypasses the high resistance), to an acceptably low level. It does this by minimizing their effective coupling area and the effective dielectric constant between them, which is primarily air.

A primary aspect of preventing a voltage pulse is to reduce the initial voltage seen by plug contact 7 upon insertion of the plug 6 into the receptacle 8. Referring to the test setup 94 and the graph of Figure 2, it can clearly be seen that the resistive portion 12 reduces the initial voltage seen by the receptacle contact 15. The graph represents the voltage seen by the receptacle contact 15 as the plug 6 is removed from the receptacle 8. Referring to the portion of the graph to the left of point 92, this shows a short circuit voltage of 0V across the plug contact 7 while the plug contact 7 is in full contact with the receptacle contact



15. At point **92**, the receptacle contact **15** contacts the resistive portion **12**. The resistive portion **12** permits the voltage as seen across the receptacle contact **15**, to increase gradually along the sloped (or curved) portion **93** of the graph as the plug **6** is removed from the receptacle **8**. At point **91**, the receptacle contact **15** no longer contacts the plug contact **7**. Accordingly, 5V is seen by the receptacle contact **15**. Curve **93** shows the gradual transition between points **91** and **92** which prevents voltage pulses which will prevent the introduction of errors into the system. Obviously, one skilled in the art would clearly recognize that the graph would be reversed upon insertion of a plug **6** into a receptacle **8**.

15 The high resistance of resistive portion **12** limits the rate of flow of current from the system bus to the "cold" device being hot-plugged into the system. The evidence of too fast a current transfer is a transient voltage pulse at the connection to the operating system.

20 The transient voltage pulse decays as it propagates along the system bus, primarily because the bus and other attached devices are sources of charge. Accordingly, the high resistance slows the charge transfer enough to provide time for the charge to be adequately replaced. If the voltage cannot dip below the sensing threshold of an adjacent device, an error cannot occur.

A 14 > Figure 3 is a graph of the electrical resistance as measured from the end of the plug contact **7**. This graph is based on a resistive portion **12** of a rectangular shape 13 mils wide and 15 mils long. The high resistive material had a resistivity of  $9 \times 10^{10}$  ohm-inches. As shown, the resistance increases as the thickness of the

resistive portion 12 increases. Referring to curve 20, when a resistive portion thickness of 8 mils is used, a resistance of 10 MW is achieved at the first end 11 of the plug contact 7, which gradually decreases until the second end 13 is reached where the resistance is nominally zero. Curves 21, 22 and 23 illustrate that the resistance decreases with a decrease in resistive portion thickness. The shape of the curves also differs as the resistive portion thickness is changed.

Referring to Figure 4, the thickness of the resistive portion 12 was kept constant at 4 mils while the resistivity of the resistive portion 12 was varied.

Curve 31 illustrates a high resistivity of  $1.8 \times 10^{11}$  ohm inches. The resistance measured at the first end 11 of the plug contact 7 is almost 16 megohms, which decreases gradually to zero at the second end 13. Curves 32 and 33 illustrate that as the resistivity of the material is decreased, the resistance measured along the plug contact 7 will also decrease.

By changing both the resistivity and the thickness of the resistive portion 12, as those skilled in the art will realize, the present invention can be adapted to different uses and applications. However, it is also extremely important to reduce the short capacitance to a negligible level. The short capacitance is reduced by keeping the thickness of the inlay 12 relatively thick, (i.e. in applying the present invention to a SCSI Bus, typically approximately 5 mils). By adjusting the resistivity and thickness of the portion, connector assemblies can be created with desirable characteristics by preventing voltage surges for various types of signals and applications.

A16 > Alternative embodiments of the present invention are shown in **Figures 5a-5h**. In the embodiment depicted in **Figure 5a**, the resistive portion **12** has a tapered profile. By varying the shape of the tapered profile  
 5 **13**, the resistive transition curves that result as the receptacle contact **15** passes over the resistive portion **12** can be varied as desired for a particular application.

A17 > **Figure 5b** depicts an alternative embodiment with  
 10 the resistive portion **12** in a stepwise-tapered profile **17**. By varying the steps between the steps, the resistive transition curves can be varied as desired.

A18 > A third alternative embodiment is shown in **Figure 5c**. The resistive portion **12** consists of two or more  
 15 materials with varying resistivities.

A19 > **Figure 5d**, a fourth alternative embodiment shows, the resistive portion **12** extending from the conducting portion **14**. A conducting barb **18** extends from the conducting body **14** into the resistive portion **12**. A  
 20 fifth alternative embodiment, **Figure 5e**, has the resistive portion **12** extending into a hole **19** in the conducting portion **14**. As those skilled in the art will note many other variations are possible without departing from the spirit of the invention. These  
 25 varying embodiments can be used for varying the resistive transition curves for differing applications.

A20 > **Figure 5f** depicts a sixth embodiment. The conductive body **14** is surrounded by a high resistive housing **30**. Receptacle contact **15** first makes contact  
 30 with high resistive housing **30**. As the receptacle contact **15** makes contact with conducting portion **14**, the receptacle contact sees essentially no resistance.

**A21** In **Figure 5g**, the housing **30** is non-conductive.

However, high resistive portions **12** make initial contact with receptacle contact **15**. The high resistive portions **12** are electrically connected and may be physically  
5 connected (not shown) to conducting portion **14**.

**A22** **Figures 5h and 5i** depict a plug **7** having a housing **85** surrounding a first high resistance **31** portion and a second low resistance portion **32**. Upon full mating, the receptacle contact **15** is in full contact with the low  
10 resistance portion **32**.

**A23** **Figure 6** illustrates that the present instant invention may also be used with the contacts on a printed circuit board. The resistive portions **70A-N** of the instant invention may be employed in one or more  
15 plug contacts **72A-N** on a conventional printed circuit board **71**. **Figure 7** shows that the present invention may be adapted to various shaped applications. For instance, a plug **83** with a cylindrical shape with a resistive portion **81** and conductive portion **82**.  
20 Receptacle contacts **84** within the receptacle **85** make contact with the resistive portion **81** prior to the conductive portion **82**.

**A24** **Figure 8** illustrates some prior art electrical connectors. The size and shape of the connectors vary.  
25 As those skilled in the art will realize, the present invention can be used with the contacts within these various connectors.

Although the invention has been described in part by making detailed reference to certain specific  
30 embodiments, such details are intended to be instructive rather than restrictive. It will be appreciated by those skilled in the art that many variations may be made in the structure and mode of operation without

departing from the spirit and scope of the invention as disclosed in the teachings herein.